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Organic Mulch and Compost Synergy Revitalizes Soil Multifunctionality for Resilient Agroecosystems

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Abstract: Soil multifunctionality (SMF) encompasses key soil functions, such as organic matter transformation, nutrient cycling, water storage, carbon sequestration, and biodiversity support for resilient agroecosystems. These vital processes promote soil structuration that supports nutrient supply, primary production, climate regulation, erosion control, and water filtration capacities. However, their success depends on the strategic integration of organic mulch and compost within holistic, context-specific farming systems. This review, therefore, synthesizes the current scientific understanding of the roles of organic mulch and compost, with a focus on soil multifunctionality. This is because soil functions still face many challenges stemming from human activities such as deforestation, overcultivation, and the intensive use of external farm inputs. These changes place mounting stress on soil ecosystems. By adopting these strategies, stakeholders can strengthen soil multifunctionality and safeguard the soil for both ecosystems and human well-being. Organic residues have been used repeatedly in sustainable farming, with compost and mulching being the most common practices, and therefore align with the UN Sustainable Development Goals in terms of environmental conservation and protection. Organic mulch, such as crop residues, conserves soil moisture, moderates' temperature, reduces erosion and promotes microbial activity, thereby improving nutrient availability and soil structure. Compost, derived from decomposed organic materials, enriches soil with essential nutrients, enhances water-holding capacity and supports microbial biodiversity, thereby contributing to long-term soil fertility and carbon sequestration. The integrated use of mulch and compost enhances nutrient availability, increases soil organic carbon and mitigates environmental stressors such as drought and erosion. These practices align with agroecological principles, reducing reliance on chemical inputs and promoting circular economy models. By improving soil aggregation, water infiltration, and microbial necromass carbon buildup, mulch and compost restore degraded lands and enhance crop productivity and yield stability. Despite challenges such as nitrogen immobilization and scalability, their combined application offers a sustainable pathway to address food insecurity and the impacts of climate change. This review underscores the need for context-specific strategies to optimize these practices, highlighting their role in revitalizing soil multifunctionality for resilient agroecosystems.

Introduction

Among the factors of production in an agricultural setup, soil is a major component that is fundamental in the storage and provision of nutrients and water, as well as plants' anchorage (Usharani et al., 2019; Balliu et al., 2021; Huntley, 2023). Soil also harbors diverse microscopic microorganisms, such as bacteria, archaea, and fungi (Sakha et al., 2025a), which play critical roles in

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ecosystem functioning, such as regulation of organic matter decomposition and soil carbon dynamics and mediating nutrient cycling (Wagg et al., 2014; Chen et al., 2024; Zhan, 2024). This component is threatened by frequent degradation through natural or anthropogenic processes (Gomiero, 2016; Bisht et al., 2020; Hossain et al., 2020; Nungula et al., 2023; Scherzinger et al., 2024; Maitra et al., 2025). Soil is a non-renewable resource because of the duration it takes to be replenished following its degradation (Abdullahi et al., 2023; Adhikary et al., 2024; Rathi et al., 2024; Raza et al., 2025). Poor soil and water conservation measures have reduced crop production due to high nutrient losses, increased runoff, and poor water-use efficiency (Ibrahim et al., 2020; Kodzwa et al., 2020; Silva et al., 2019).

Sustainable farming requires the use of environmentally friendly inputs that not only supply nutrients to the crops but also protect the land from further losses (Otieno et al., 2022; Githumbi et al., 2025). Essentially, maintaining sustainable soil management practices enhances its multifunctionality (Manning et al., 2018; Ying et al., 2023; Liang et al., 2025), which is imperative in addressing issues such as degradation (Srinivasarao et al., 2021; Maitra et al., 2023; Tefera et al., 2024; Mishra et al., 2025). Several studies have reported on the soil health (Gurmu, 2019; Miner et al., 2020; Shahane and Shivay, 2021; Palai et al., 2024; Priyadarshani et al., 2025; Xing et al., 2025) and soil quality (Bonfante et al., 2019; Aulakh et al., 2022) and their contributions to crop productivity, with less focus on its multifunctionality. Soil multifunctionality is the ability of the soil to simultaneously provide multiple functions and services both to the plants and the ecosystem, such as organic matter transformation, nutrient cycling and soil structuration, supporting nutrient supply, primary production, climate regulation, erosion control and water filtration (Delgado-Baquerizo et al., 2016; Jamal et al., 2022; Bünemann et al., 2024; Santosh et al., 2024). It provides for a more comprehensive assessment of the impact of different agricultural and management practices on soil functions and ecosystem services (Davis et al., 2023; Scherzinger et al., 2024). These interconnected soil functions contribute to the resilience of several agroecosystems, sustainable agricultural production, and environmental health (Diyaolu and Folarin, 2024). Good soil structure, microbial abundance and diversity and other key soil biochemical activities, its multifunctionality results in long-term crop production while reducing the impacts of the practices on climate change and environmental pollution (Moses et al., 2022; Luo et al., 2018; Ngugi et al., 2022; Telo da Gama, 2023; Sagar et al., 2024: Sakha et al., 2025b).

Soil multifunctionality is threatened by severe soil erosion on agricultural lands, making them unable to support food production (Shi et al., 2025). Organic residues have been used repeatedly in sustainable farming, with compost and mulching being the common ones, aligning with the sustainable development goals of the UN for environmental protection (Hettiarachchi et al., 2020; Rahimi et al., 2023; Mohammad et al., 2025; Rathi et al., 2024; Onyuka et al., 2025). Sustainable soil management practices, such as the application of organic amendments, positively affect the soil multifunctionality (Tamburini et al., 2020; Selvan et al., 2023).

Organic materials ensure the use of natural resources rather than relying on external inputs. By focusing on the use of natural resources that are considered abundant and can be within the reach of the farmers, these practices increase their autonomy in deciding the type of inputs to use in their farms, forming an integral part of ecosystem management (Campos et al., 2021). Organic materials use natural resources instead than relying on things that come from outside sources. These methods provide farmers more freedom to choose what inputs to use on their farms by focusing on using natural resources that are seen as plentiful and accessible to them. This is an important part of managing ecosystems. This method helps create a more sustainable agricultural system by reducing harm to the environment and strengthening the economy in the area. Also, using organic methods helps create a circular economy in agriculture, where by-products are turned into organic fertilizers and biopesticides. This cuts down on waste and reliance on outside sources. This commitment to avoiding synthetic chemicals in favor of natural and organic inputs sets organic farming apart from other types of farming.

Maintaining the soil multifunctionality through sustainable soil management is a major global challenge. Thus, this review contextualizes and contributes to the already existing literature on the contributions of specific organic mulch-compost practices to soil multifunctionality by analyzing several studies to provide exhaustive evidence on sustainable farming.

Our review may help to expound on the different roles of these organic materials in enhancing agroecosystem resilience to different environmental stresses that may hinder its functions. It is important to highlight that in this paper, we do not define soil multifunctionality on ourselves, but rather shed light on the existing definitions by focusing on its roles towards ecosystem resilience. In achieving the goal of this review, therefore, previous

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studies conducted specifically on the two practices and focusing on the agricultural benefits were evaluated and their contributions to soil multifunctionality were identified. The rapid review methodology adopted ensured that existing evidences were systematically summarised both at the regional and global levels.

Materials and Methods

The process involved in the literature review is illustrated in Figure 1:

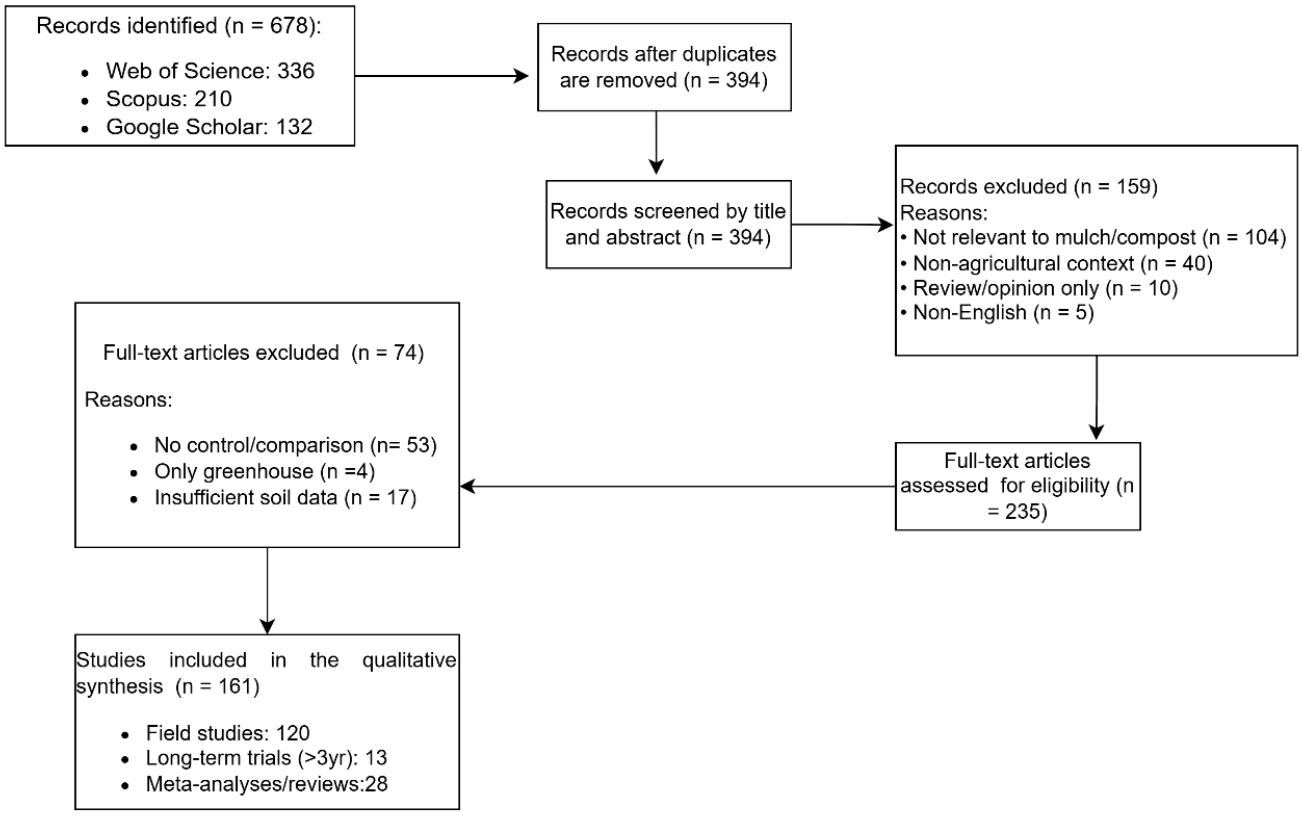
Records identified (n = 678):
Web of Science: 336
Scopus: 210
Google Scholar: 132
Records after duplicates are removed (n = 394)
Records screened by title and abstract (n = 394)
Records excluded (n = 159)
Reasons:
• Not relevant to mulch/compost (n = 104)
• Non-agricultural context (n = 40)
• Review/opinion only (n = 10)
• Non-English (n = 5)
Full-text articles assessed for eligibility (n = 235)
Full-text articles excluded (n = 74)
Reasons:
No control/comparison (n= 53)
Only greenhouse (n =4)
Insufficient soil data (n = 17)
Studies included in the qualitative synthesis (n = 161)
Field studies: 120
Long-term trials (>3yr): 13
Meta-analyses/reviews:28

Figure 1. Literature review process.

Result and Discussion

Mechanisms of Mulch and Compost in Soil Enhancement

Mulch: Functions and Mechanisms

Mulch can be either organic or inorganic materials used to cover the soil surface, primarily to reduce soil moisture loss (Kader et al., 2019). These materials also control weeds, stabilize the soil, and control soil-borne pests and diseases. The use of organic materials as mulch is effective due to their affordability and environmental friendliness, as they reduce microplastic pollution (Steinmetz et al., 2016; Ocharo et al., 2017; Paul et al., 2024; Sairam et al., 2025; Saputra et al., 2025). The carbon-to-nitrogen ratio should be considered when deciding on the type and amount of mulch to apply. For instance, materials with a high C:N ratio decompose slowly, thereby hindering microbial breakdown (Amuah et al., 2022). Organic mulches can decompose and release nutrients into the soil, making them mostly preferred in soil fertility management (Kaur et al., 2021). Crop residues after harvests, otherwise referred to as the straws, can be satisfactorily used as mulch in agricultural farms (Rhioui et al., 2023), being that they are abundant and cheap (Li et al., 2021) and easy to apply (Girona-García et al., 2023). These mulches create microclimatic conditions around plant roots, enhancing nutrient and water uptake to support crop metabolic processes (Pal and Mahajan, 2017; Dong et al., 2018). Organic mulching is important for influencing root performance by maintaining soil properties (Aslam et al., 2021). This is achieved by reducing water losses (Yu et al., 2018), preventing weed emergence (Alhashimi et al., 2023), promoting microbial activities (Kader et al., 2017), and regulating soil temperature (Moursy et al., 2015; 2021), which facilitates the acquisition of plant nutrients by their roots. Mulch controls soil moisture losses by creating a barrier between the soil and the external temperature to reduce evapotranspiration rates (Biswas et al., 2022; Wang et al., 2021). Mulching affects the structural and functional activities of microorganisms (Chen et al., 2018), thus ensuring ecological sustainability by cycling organic bioenergy (Liu et al., 2017; Ngowi et al., 2025; Guo et al., 2022; Sun et al., 2021).

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Mulching enhances the population of soil organisms by regulating rhizosphere conditions such as temperature and moisture (Sun et al., 2021; Mohammad et al., 2025; Liang et al., 2025). The retained moisture creates conducive conditions for microorganism functions and other enzymatic activities (Akhtar et al., 2019). Rather than preventing direct evaporation of moisture, organic mulch also produces humus during decomposition, which not only reduces moisture loss but also acts as a carbon sink (Durán-Lara et al., 2020). Studies by Kader et al. (2019) and Wang et al. (2020) have reported that mulching helps insulate the soil, moderating its temperature and supporting plant growth across different seasons. By moderating the soil temperature, the important activities of the soil microorganisms are accelerated (Qu et al., 2023; Zhou et al., 2024), and support germination of crop seeds and provide sufficient water during germination (Khaskheli et al., 2021). Mulching stimulates microbial interactions with soil fauna, responsible for mineralization of soil nutrients, and carbon and nitrogen cycles (Kou et al., 2020). Soil microbes, such as fungi, facilitate the transformation of straw into carbon and nitrogen during decomposition (Cong et al., 2024), making these nutrients available for root uptake (Maarastawi et al., 2019).

Organic mulch reduces water erosion, such as splash (Iqbal et al., 2020) and rill or sheet (Alhashimi et al., 2023), by acting as a sponge against the outcome of heavy rainfalls. By shielding the soil from raindrops, mulching protects soil aggregates and leads to the rapid formation of soil macroaggregates, promoting fungal proliferation (Wang et al., 2022). Straw mulch improves soil microclimatic conditions, which, in turn, encourage root growth, expansion, and exudation, thereby improving nutrient accessibility (Liang et al., 2025). These conditions also maintain a higher relative water content in leaves and stabilize chlorophyll content under low soil water availability (Irshad et al., 2022). Organic mulches influence soil bulk density and organic carbon, improving soil quality (Awad et al., 2025).

Compost: Functions and Mechanisms

Compost consists of decomposed organic materials that have undergone biochemical processes, forming a stable, light, and low-volume product (Bher et al., 2023; Insam et al., 2023), which is capable of releasing nutrients (Rynk et al., 2022) and can be easily absorbed by plants (Bagagiolo et al., 2022). The preparation is easy and requires few resources, improving soil productivity by providing good tilth for seed germination and plant growth. Compost promotes circular economy models by reducing reliance on chemical fertilizers (Nduwimana et al., 2020; Sultana et al., 2021; Saeid et al., 2023). The circular economy is a conservation paradigm that concerns the environment, human health, and socioeconomic conditions (Ireri et al., 2019; Cheptoek et al., 2021; Oliveira et al., 2021). It involves the breakdown of organic materials, such as waste and plant residues, transforming them into stable products composed of a variety of plant nutrients. By reducing the volume of the waste, the storage and transportation of the product become extremely easy. The thermophilic conditions during composting destroy pathogens and weed seeds that can transmit diseases and compete with crops for resources (Ayilara et al., 2020; Waqas et al., 2023).

Applying mature compost to the soil enhances soil fertility and improves nutrient supply to the plants (Kelbesa, 2021). Compost manure has been reported to promote phosphorus recovery in soils with low phosphorus availability and reduce their losses (Kumaragamage and Akinremi, 2018). Additionally, long-term application increases the availability of nitrogen, phosphorus, potassium, magnesium, and calcium. Compost improves soil structure, aeration, water holding capacity, and nutrient retention (Adugna, 2016; Kelbesa, 2021; Ntinyari and Gweyi-Onyango, 2021). By lowering soil bulk density, compost reduces compaction and increases soil porosity, thereby enhancing root penetration. Adding compost to the soil raises the pH, making it easier for nutrients to be absorbed by plants (Goldan et al., 2023). It also raises the soil cation-exchange capacity (CEC), thereby reducing the likelihood of leaching (Khadim et al., 2024). Compost also induces resistance against plant diseases and reduces soil salinity, benefiting crops such as tomatoes (Ud Din et al., 2023). It improves soil biological properties by increasing microbial populations, thereby promoting nutrient cycling and enhancing soil fertility.

Synergistic Interactions

The integrated use of mulch and compost promotes the abundance and diversity of soil microbial communities, increasing crop yields (Awad et al., 2025). Compost and straw mulch significantly increase organic matter and soil structure, maintaining nutrient balance (Dai et al., 2024; Meng et al., 2024). They increase readily oxidizable and particulate organic carbon, elevating soil organic carbon levels (Hao et al., 2022; Mwadalu et al., 2022). Organic materials support soil microorganisms, enhancing soil carbon and macronutrient levels. Integrated use promotes nutrient availability and microorganisms' stoichiometric demands, enhancing soil microclimate and nutrient release (Liu et al., 2021; Zhu et al., 2019; Francioli et al., 2016). Organic materials reduce the loss and degradation of soil organic carbon and nutrients (Keesstra et al., 2024; Malo

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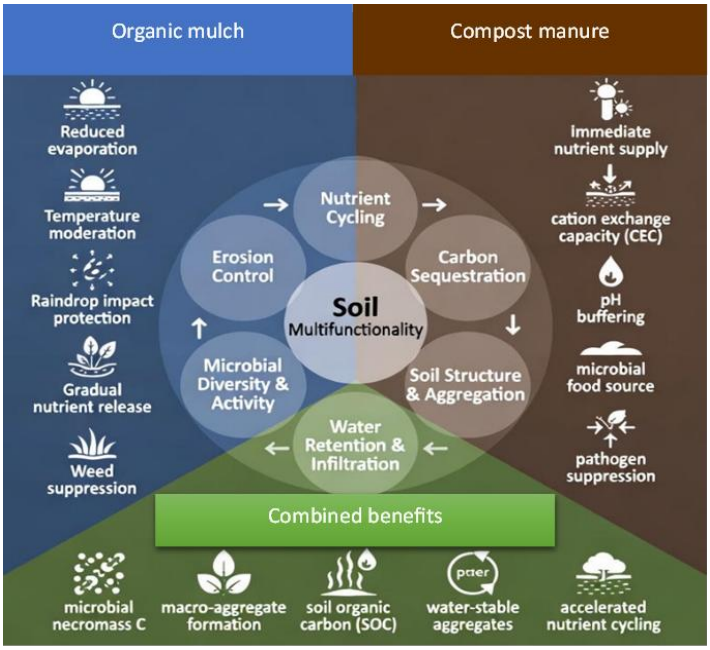
et al., 2024; Miao et al., 2019). Figure 2 below clearly shows how these synergistic interactions lead to soil multifunctionality.

Figure 2. Conceptual diagram of the synergistic mechanisms of organic mulch and compost on soil multifunctionality.



Impacts on soil multifunctionality

Nutrient Cycling and Availability

Several research works have been carried out on the combined or sole effects of mulch and compost on the soil multifunctionality (Table 1). Manure such as compost improves nutrient cycling and transformations, enhancing soil fertility and nutrient uptake in crops (Asrade et al., 2022; Giannitsopoulos et al., 2023; Kumari et al., 2024). They boost microbial activities, promoting nutrient availability through enzymatic processes (Niu et al., 2024; Raj et al., 2025). Organic materials enhance soil microbial activities, improving nutrient availability for crop absorption (Luo et al., 2018; Faridvand et al., 2021; Prats et al., 2023; Liu et al., 2024). Compost stabilizes the carbon-to-nitrogen ratio, increasing nitrogen, phosphorus, and potassium levels (Xie et al., 2024). Mulching increases nitrogen use efficiency in maize and wheat and reduces nitrogen loss through leaching, though immobilization may occur during fungal decomposition (Yang et al., 2022; Cao et al., 2018). Organic manure enhances microbial anabolism, promoting microbial necromass carbon buildup (Chen et al., 2020; Zhu et al., 2019). Mulch influences nutrient composition, increasing leaf nitrogen and phosphorus concentrations (Nurzadeh et al., 2018; Awad et al., 2025). Prolonged use of animal manure increases nitrogen and phosphorus levels in the soil (Govednik et al., 2023; Xie et al., 2024). These materials have long-term benefits by gradually releasing nutrients to support multiple cropping seasons (Dutta et al., 2024; Ayamba et al., 2023).

Soil Structure and Physical Properties

Compost and organic mulch contribute to soil aggregation, improving organic matter content and microbial necromass carbon buildup (Tian et al., 2022). They reduce soil compaction, increase water infiltration, and decrease erosion by reducing runoff speed (Wortmann and Shapiro, 2008). Mulching increases surface roughness, reduces soil sealing, and promotes water infiltration, strengthening soil structure in degraded lands (El-Beltagi et al., 2022; Prats et al., 2019; Prosdocimi et al., 2016). It reduces sediment transportation and rill erosion, increasing aggregate stability (Abrantes et al., 2018; He et al., 2018). Organic materials improve soil porosity and water retention under water stress conditions (Mahmood et al., 2023). Among the available organic amendments, compost stands out as the most common, significantly increasing soil organic matter and influencing soil nutritional capacity (Urra et al., 2019).

Water Retention and Hydrological Functions

Mulching improves soil water holding capacity, porosity, and infiltration, reducing evaporation and runoff (Abdel-Mageed et al., 2018; Nyawade et al., 2021; Thakur and Kumar, 2021). It intercepts raindrops, promotes infiltration, and maintains soil moisture for crop growth, enhancing root development and stomatal conductance (Kader et al., 2017; El-Beltagi et al., 2022). Compost increases water storage capacity, particularly in clay-rich soils, preventing excessive water retention or loss (Saputra et al., 2025; Adugna, 2016; Sayara et al., 2020). Both practices improve water use efficiency, reduce irrigation needs, and facilitate water movements for nitrate distribution (Saglam et al., 2017; Shen et al., 2023; Meng et al., 2024).

Carbon Sequestration and Climate Regulation

Compost and mulch increase soil organic carbon through microbial activity and decomposition (Heydarzadeh et al., 2021; Chepkorir et al., 2024; Zhang et al., 2025), with a good example being microbial necromass carbon buildup, which enhances carbon sequestration (Buckeridge et al., 2022; Liang et al., 2019). It promotes microbial biomass and enzymatic functions, contributing to nutrient cycling and carbon sequestration (Li et al., 2023; Nasar et al., 2022). Mulching reduces dissolved organic carbon loss through runoff, stabilizing soil aggregates (Zhang et al., 2020 Ajirlu et al., 2024). Straw mulch regulates microbial communities and soil carbon fractions (Wang et al., 2019; Cong et al., 2024).

Table 1. Thematic synthesis of empirical evidence on the effects of organic mulch and compost (alone and in combination) on soil multifunctionality across physical, chemical, biological and productivity dimensions.

Theme	Sub-Metrics	Treatment Details	Quantitative Findings	Authors
Physical Properties	Soil structure and aggregation	Straw mulch; compost	Increased macro-aggregates; increased water-stable aggregates	Wang et al. (2023) (long-term straw on aggregation); Ying et al. (2023) (fertilization on structure)
	Water retention and infiltration	Rice/maize stover mulch; compost	Increased retention; higher infiltration rate; increased WUE	Wang et al. (2021) (mulch thickness for conservation); Sun et al. (2021) (deep SOC via mulch)
	Erosion control	Various organic mulches	Reduced erosion; soil cover stability	Tefera et al. (2024) (intensification in SSA); Ibrahim et al. (2020) (runoff losses)
Chemical Properties	Nutrient cycling and availability	Straw mulch; compost	Increased available N; accelerated cycling via microbes	Shahane and Shivay (2021) (nutrient balance); Ud Din et al. (2023) and Ngaiza et al. 2025 (biochar-compost on nutrients)
	Soil organic carbon (SOC) and Sequestration	Organic mulch; soil amendments,	Increased SOC; deep layer accumulation	Meng et al. (2024); Zhang et al. (2025) (manure on C stability)
	pH Buffering and CEC	Compost only or combined	Improved CEC; pH stabilization	Aulakh et al. (2022) (soil quality); Usharani et al. (2019) (properties for health)
Biological Properties	Microbial diversity and activity	Biodiversity amendments	Higher biomass C; enhanced decomposition	Chen et al. (2024) (C dynamics); Wang et al. (2020) (bacterial-fungal networks)
	Pathogen suppression and biodiversity	Mulch/compost in systems	Higher beneficial microbes; decreased pathogens	Tamburini et al. (2020) (diversification services); Balliu et al. (2021) (microbes in anchorage)
Yield and Resilience	Crop productivity and yield Stability	Mulch; compost	Improved yields; yield stability under stress	Nyambo et al. (2021) (CA yields); Xing et al. (2025) (health-productivity link)
	Climate regulation and ecosystem Services	Diversified practices	Higher sequestration; enhanced services without yield loss	Gomiero (2016) (degradation); Manning et al. (2018) (multifunctionality)

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Levels of organic matter in the soil influence agroecosystems' productivity and climate-change resilience (Ray et al., 2025).

Biodiversity and Microbial Activity

Soil quality degradation has been linked to reduced soil organic matter content, leading to declines in crop productivity (Sagar et al., 2025). Mulch and compost promote microbial diversity and abundance, enhancing

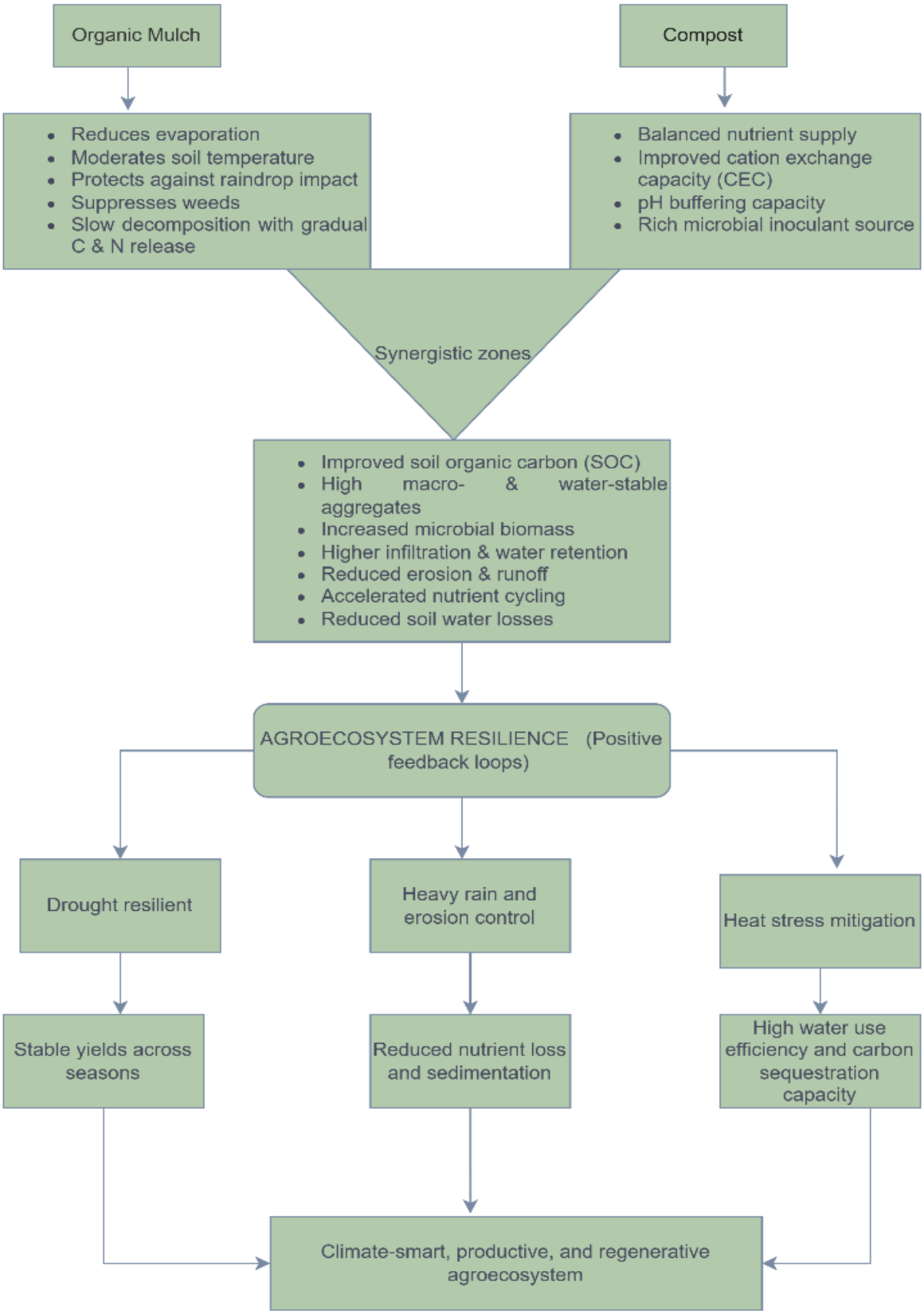

Figure 3. Pathway to Agroecosystem Resilience.

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nutrient cycling and ecosystem stability (Awad et al., 2025). They support macrofauna, such as earthworms, and increase enzymatic activity (Brodhagen et al., 2015). Organic amendments reduce heavy metal uptake by plant roots, protecting biodiversity (Zeeshan et al., 2024; Moses et al., 2022). Soil amendments using compost and organic materials enhance microbial biomass and soil organic matter (Angst et al., 2024). Straw mulching improves soil multifunctionality, with bacterial abundance being key (Wu et al., 2025).

Applications in agroecosystems

Crop Productivity and Yield Stability

Many consumers have preferred healthy and eco-friendly products, making organic production an important practice (Willer and Lernoud, 2018). Mulching improves crop yields in crops such as onions, maize, and wheat by moderating the soil microclimate, conserving moisture, and reducing weed competition (Prem et al., 2022; Yang et al., 2020). It maintains leaf water potential and chlorophyll content, protecting plants from dehydration (Gholami and Madandoust, 2024). Compost enhances plant growth under drought conditions, thereby improving the nutritional quality of leafy vegetables (Saputra et al., 2025). Both practices stabilize yields by providing optimal conditions for root growth and nutrient transport (Kader et al., 2019).

Soil Health Restoration in Degraded Systems

Restoring degraded lands has an indirect influence on water quality and vegetation conservation, boosting food production and resilience against climate change (Noel, 2016). Mulch and compost restore degraded lands by improving soil organic carbon, nutrient composition, and structure. Straw mulching reduces erosion and runoff, conserving soil and water resources (Ranaivoson et al., 2017; Keesstra et al., 2024; Iqbal et al., 2020). Compost enhances nutrient availability and microbial activity, supporting vegetation restoration (Liu et al., 2024). These practices mitigate nutrient depletion in arid areas, enhancing land productivity (Nehrani et al., 2020).

Integration with Farming Systems

Continuous cultivation of the soil without replacement significantly reduces the organic matter content, affecting soil fertility (Richardville et al., 2022). Sustainable farming involves agricultural practices that restore farming systems, addressing the holistic nature of farming by ensuring resilience through healthy soils (Sumit et al., 2024; Falconnier et al., 2023; Sakha and Gweyi-Onyango, 2024). Mulch and compost increase soil organic matter, stabilize soil structure, and enhance water use efficiency (Gomiero et al., 2016). Compost improves nutrient availability and soil biological functions, while mulch reduces erosion and conserves moisture. These practices promote a circular economy by utilizing crop residues and organic wastes, reducing dependence on external inputs (Orgiazzi et al., 2016; Santos et al., 2022).

Synergistic benefits for agroecosystem resilience

Adaptation to Climate Variability

Water stress caused by prolonged drought is expected to increase due to climate change problems, significantly affecting food production (Wahab et al., 2022; Sagar et al., 2025). Mulch and compost mitigate water stress caused by drought, maintaining soil moisture and supporting crop growth under variable climatic conditions (Nadeem et al., 2019; Zhu et al., 2021). They optimize resource use, reducing environmental impacts while ensuring food production stability.

Mitigation of Environmental Stressors

Mulching reduces erosion on sloping lands and moderates soil temperature. Compost protects plants from abiotic stresses like drought and frost (Saputra et al., 2025). The effectiveness of mulching depends on material type, thickness, and soil properties (Prats et al., 2019). Mulch thickness affects efficiency, with high thicknesses potentially increasing erosion or costs (Wang et al., 2021).

Long-Term Sustainability

Compost and mulch promote sustainable farming by improving soil organic matter, water holding capacity, and nutrient cycling. They protect plants from environmental stresses, support seed germination, and enhance nutritional quality (Saputra et al., 2025). These practices contribute to long-term agroecosystem resilience (Figure 3).

Challenges and limitations

Practical and Logistical Constraints

Compost production faces challenges like nitrogen immobilization, scalability, and quality control (Nyambo et al., 2021). Poor management of compost piles leads to nutrient losses through volatilization, producing greenhouse gases like methane and nitrous oxide. Nutrient release from compost may not match crop demand, necessitating supplementation with inorganic fertilizers (Shao et al., 2023). Mulching effectiveness depends on the type and quantity of material, with high C:N ratios slowing decomposition. The materials used for compost preparation should have a reduced C:N ratio to minimize nitrogen immobilization during decomposition (Shi et al., 2025). The costs can be high when compost manure is used improperly, necessitating optimization of application rates to achieve long-term sustainability (Shao et al. 2024).

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Environmental and Contextual Variability

The benefit of mulching material depends on the type, quantity, and soil properties (Rahma et al., 2019). Environmental factors like rainfall, temperature, and slope affect mulching efficiency (Kader et al., 2017; Busari et al., 2022). Soil type also affects the suitability of mulching materials (Rahma et al., 2019). The type of mulch, decomposition period, application duration, and thickness applied affect its effectiveness (Prats et al., 2023; Wang et al., 2022).

Conclusion

The study has revealed that soil has various functions, such as organic matter transformation, water storage, carbon sequestration, nutrient cycling, and biodiversity support. The review has synthesized the current scientific understanding of the roles played by organic mulch and compost, with a focus on soil multifunctionality. The study has shown that stakeholders can strengthen soil multifunctionality and safeguard the soil for both ecosystems and human well-being. Organic mulch, such as crop residues, conserves soil moisture, moderates temperature, reduces erosion, and promotes microbial activity, thereby improving nutrient availability and soil structure. The integrated use of mulch and compost fosters nutrient availability, increases soil organic carbon, and mitigates environmental stressors like drought and erosion. Hence, the review has underscored the need for context-specific strategies to optimize these practices, highlighting their role in revitalizing soil multifunctionality for resilient agroecosystems.

Conflict of interest

The authors declared no conflict of interest with regard to this publication.

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